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COMMENTARY

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Cuff-less blood pressure measurement with pulse transit time: The importance of rigorous assessment

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Hypertension leads all other risk factors in the reduction of disability-adjusted life years.[1] Despite its commonality and morbidity, hypertension screening and control continues to be suboptimal.[2] Home cuff-based blood pressure (BP) monitors are cumbersome and uncomfortable, which we think limits their potential for widespread adoption in hypertension screening and monitoring of BP control among those known to have the condition. Non-invasive BP monitors with the convenience of a smartwatch might overcome such barriers and aid hypertension detection and control efforts. One potential technology utilizes pulse transit time (PTT) to measure BP, and users report this method to be more convenient than cuff-based methods.[3] PTT represents the time it takes for a pulse wave to travel from the heart to a peripheral point and is typically measured using the R-wave on electrocardiogram and a finger or wrist plethysmography sensor. PTT shortens when BP increases as described by the Moens–Korteweg Equation.[4] In short, the equation describes that arteries become stiffer when they are distended at a higher BP, and a pulse wave travels faster through a rigid tube than through an elastic tube. PTT devices must be calibrated at first use against a standard device to accommodate for differences in arterial elasticity. As with all new technologies, it is essential that PTT-based devices undergo rigorous assessment in order to ensure the accuracy of the measurements and inform their use in clinical practice. Conventional BP monitor validation protocols compare a static series of measurements from an investigational and reference device, and a PTT device that simply repeats back the calibration BP will meet accuracy criteria since the calibration BP and the reference device BP are the same.[5] More appropriate validation protocols for PTT devices include validation measurements after changes in BP and after hours or days since calibration.[6,7] Clinical studies of PTT devices might include an extended comparison against a reference device to take advantage of naturally occurring variations in BP throughout a 24-hour period. Specifically, BP is known to dip at nighttime in some people,[8] and a PTT-based BP device should detect these dips at the same frequency as the reference device. Rigorous assessment of PTT devices would compare throughout a day against an automated 24-hour cuff-based monitoring device.

In this issue of the Journal of Clinical Hypertension, Nyvad et al[9] report a clinical comparison between 24-hour BP measurements obtained with 1) A PTT-based cuff-less BP measurement device running two different variations of software (SOMNOtouch, SOMNOmedics, Randersacker, Germany) and, 2) A validated cuff-based automated oscillometric BP measurement device (SPACELABS 90217, Snoqualmie, WA, USA).[10] The researchers are to be applauded for a thoughtful, rigorous assessment that included 51 adult participants with a wide spread of baseline systolic BPs. Correlation between hypertension-level measurements from the SOMNOtouch and reference devices was poor, especially overnight. The reference device observed a nighttime dip in systolic and diastolic measurements in 45% and 73% of participants, respectively. The two software versions of SOMNOtouch only identified systolic nighttime dipping in 2% and 22% and diastolic dipping in 16% and 0%. Specifically, the reference device recorded mean daytime BP that was higher (142 ± 20/83 ± 11 mm Hg) than mean nighttime BP (129 ± 20/72 ± 10 mm Hg). In contrast, the observed SOMNOtouch BP was similar between daytime (148 ± 25/85 ± 13 and 147 ± 20/84 ± 14 mm Hg for each software version) and nighttime (146 ± 26/84 ± 13 and 141 ± 28/81 ± 14 mm Hg).

The findings from the present manuscript expand the amassing documentation of poor performance of PTT-based BP monitors.[11-13] Obtaining validation measurements immediately after calibration at the same BP falsely establishes accuracy and precision of PTT

devices[14] as demonstrated by the results from Nyvad's work.[9] As noted by the authors, the fundamental limitation of PTT devices is that they become inaccurate when the relationship between PTT and BP changes in an individual. The mathematical PTT-based estimation of BP assumes that the heart and arteries behave like a constant pump and inert rubber tubes, ignoring the important influence of factors such as activity level and sympathetic tone. Physiological studies have demonstrated that intraindividual changes in cardiac contractility and vascular smooth muscle tone make the PTT method a poor BP estimation model.[15] The particularly poor agreement between SOMNOtouch and cuff-based BP measurements at night that Nyvad et al found seems to underscore this point, considering the SOMNOtouch was calibrated during the day.

In conclusion, the study by Nyvad et al provides important information on the limited clinical value of PTT-based BP monitors. The inherent physiological confounding of PTT-based BP estimation makes it difficult to envision that this type of measurement will have clinical utility. Other innovative cuff-less BP measurement methods that are more closely related to BP in a local blood vessel are currently being studied[16] and will hopefully eventually be found to be accurate and precise. We think that any future validation studies claiming that PTT devices are accurate should use protocols that were specifically developed for cuff-less BP measurement devices,[6,7] in addition to a meaningful clinical comparison study. Nyvad et al's effort highlights that a crucial step toward achieving confidence in the clinical use of cuff-less BP monitoring is that the marketing and sale of devices does not precede assurance of clinical accuracy and performance.

CONFLICT OF INTEREST

Dr van Helmond has no conflicts to disclose specifically relating to cuff-less blood pressure measurement. He reports having patent applications pending related to vital sign measurement. Dr Plante reports no potential conflict of interest.

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REFERENCES

1. GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* (London, England). 2018;392(10159):1923-1994.
2. Virani SS, Alonso A, Benjamin EJ, et al. Heart disease and stroke statistics-2020 update: a report from the American heart association. *Circulation*. 2020;141(9):e139-e596.
3. Plante TB, O'Kelly AC, Macfarlane ZT, et al. Trends in user ratings and reviews of a popular yet inaccurate blood pressure-measuring smartphone app. *J Am Med Inform Assoc*. 2018;25(8):1074-1079.
4. Korteweg DJ. Über die Fortpflanzungsgeschwindigkeit des Schalles in Elastischen Röhren [About the speed of wave propagation in elastic tubes]. *Ann Phys*. 1878;214:525-542.
5. Sharman JE, O'Brien E, Alpert B, et al. Lancet Commission on Hypertension group position statement on the global improvement of accuracy standards for devices that measure blood pressure. *J Hypertens*. 2020;38(1):21-29.
6. Institute of Electrical and Electronics Engineers.IEEE SA Std 1708. IEEE Standard for Wearable Cuffless Blood Pressure Measuring Devices. https://standards.ieee.org/standard/1708-2014.html. Published 2014. Accessed 11/02/2020, 2020
7. International Organization for Standardization. BS EN ISO 81060-3. Noninvasive sphygmomanometers. Part 3. Clinical investigation of continuous noninvasive automated measurement type. https://shop.bsigroup.com/ProductDetail?pid=000000000030397676. Published 2019. Accessed 11/02/2020, 2020
8. Degaute JP, van de Borne P, Linkowski P, Van Cauter E. Quantitative analysis of the 24-hour blood pressure and heart rate patterns in young men. *Hypertension* (Dallas, Tex: 1979). 1991;18(2):199-210.
9. Nyvad J, Christensen KL, Buus NH, Reinhard M. The Cuffless SOMNOtouch NIBP device shows poor agreement with a validated oscillometric device during 24-hour ambulatory blood pressure monitoring. *J Clin Hypertens* 2021;23(1):61–70.
10. Baumgart P, Kamp J. Accuracy of the SpaceLabs Medical 90217 ambulatory blood pressure monitor. *Blood Press Monit*. 1998;3(5):303-307.
11. van Helmond N, Freeman CG, Hahnen C, et al. The accuracy of blood pressure measurement by a smartwatch and a portable health device. *Hosp Pract (1995)*. 2019;47(4):211-215.
12. Krisai P, Vischer AS, Kilian L, Meienberg A, Mayr M, Burkard T. Accuracy of 24-hour ambulatory blood pressure monitoring by a novel cuffless device in clinical practice. *Heart*. 2019;105(5):399-405.
13. Plante TB, Urrea B, MacFarlane ZT, et al. Validation of the Instant Blood Pressure Smartphone App. *JAMA Intern Med*. 2016;176(5):700-702.
14. Bilo G, Zorzi C, Ochoa Munera JE, Torlasco C, Giuli V, Parati G. Validation of the Somnotouch-NIBP noninvasive continuous blood pressure monitor according to the European Society of Hypertension International Protocol revision 2010. *Blood Press Monit*. 2015;20(5):291-294.
15. Payne RA, Symeonides CN, Webb DJ, Maxwell SR. Pulse transit time measured from the ECG: an unreliable marker of beat-to-beat blood pressure. *J Applied Physiol* (Bethesda, Md : 1985). 2006;100(1):136-141.
16. Chandrasekhar A, Kim C-S, Naji M, Natarajan K, Hahn J-O, Mukkamala R. Smartphone-based blood pressure monitoring via the oscillometric finger-pressing method. *Sci Transl Med*. 2018;10(431):eaap8674.

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